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# Ecosym-Soil Classification and Mapping

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# ECOSYM - SOIL CLASSIFICATION AND MAPPING[1]

by

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# ABSTRACT

Soil classification as used in this report is the system published in Soil Taxonomy, U.S.D.A., SCS Soil Survey Staff in 1975. This is a quantiative system, comprehensive and expansible. The data used as differentiating criteria, serve as a basis for interpreting soil resources for use and management. The system has 6 categorical levels. They are 1) Order, the highest level of generalization, 2) Suborder, 3) Great Group, 4) Subgroup, 5) Family, and 6) Series, the lowest level of generalization or greatest detail.

Soils are identified in the field based on their morphological characteristics. These field data, together with laboratory data obtained from laboratory analysis, permit classification of the soil bodies delineated on soil maps.

# INTRODUCTION

## General Statement

Soil is the substrate which affords a base for plants and animals and also serves as the foundation for engineering endeavors. It serves as an important component of most of man's activities.

The characteristics of soils and how they respond to man's manipulations are an important consideration for use and management of the natural environment. Selection of management criteria for specific landscape segments should be based on a knowledge of the soils which occupy discrete portions of the landscape under consideration.

## Soil Classification Usage

The response of soils to man's manipulations can be predicted in a general way if the following soil properties are evaluated. They are: 1) particle size distribution; 2) mineralogy; 3) slope gradient; 4) depth of soil to inhibiting layer; and 5) drainage. From this data base several accessory soil characteristics can be inferred; and, in addition, several statements can be made about the response of the soil bodies to man's manipulations (use and management). Particle-size distribution and mineralogy provide a basis for inferring water-holding capacity, erodibility, infiltration rates, hydraulic conductivity, porosity, cation exchange capacity and shrink-swell potential and slope stability. The proportion of coarse fragments, their size and distribution in or on the soil are useful for general inferences about the above mentioned properties as well as indicating restraints for some uses such as logging and skiing.

Slope gradient while not acting independently does permit certain inferences about erosion potential, slippage and runoff and in certain instances, if steep enough, tends to preclude many activities on gradient alone. Soil depth translates to mean the volume of soil available for water and air storage and space for plant roots and other biological components. Runoff and erosion potential are also related to soil depth especially if the depth is shallow.

Soil drainage is the manner in which soil is able to transmit the water which is available for transmittal. Several drainage classes have been established related to the proportion of time the soil is essentially saturated with water. This condition is usually inferred by soil color in instances where the saturated condition does not persist for long periods. In some aspects the depth to the saturation zone is directly linked to soil depth or soil volume and a poorly drained soil translates directly into a soil that has limited volume for air, roots and other biological components.

## REVIEW OF LITERATURE

Early records show that 40 centuries ago the Chinese recognized 9 classes of soils based on fertility or production (Simonson 1962). Modern soil classification evidently originated with V. V. Dakuchaiev when in 1886 he developed a system of classification in Russia. Sibirtsiev, a colleague of Dakuchaiev, added the zonality concept. In the United States in 1913 Marbut, the Chief of Soil Survey in the United States, wrote of the vast importance to recognize in soil classification not only the character of the rocks from which the material had been derived but also the agencies of transportation and deposition. By 1922 Marbut had changed his mind when he wrote grouping should be based on the characteristics of objects grouped. The system of Baldwin, et al. in 1938 was strongly flavored by Sibirtsiev's zonality and this system as modified in 1949 was used in the United States until 1965 when soil taxonomy became the official soil classification system (Soil Survey Staff 1960).

Kellogg (1963) stated in response to Why a new system of classification? "The most useful soil classification is a general one that can be interpreted accurately for a wide variety of uses. No longer are we concerned mainly with how a soil behaves under simple practices. We need, rather in respect to any local kind of soil, to be able to answer the question, "What can we make of it with the technology and skills available? For many of our soil choices are made from a large number of alternatives. The system must provide for orderly subdivision into phases, and for an orderly non-ambiguous nomenclature."

Smith (1963) said in his discussion of objectives and basic assumptions of the new classification system, "In deciding which soils belong together we consider all the properties of soils that we know." We also consider what we know about how the soils acquired their properties. We consider both because we are aware that soils have many properties that we cannot yet know or that we are apt to overlook, and that our ideas of genesis are inferences often based on indirect and fragmentary evidence. The most useful classification system for our purpose is a comprehensive one, designed to permit inclusion of all soils, though any system devised now will obviously be incomplete." It can be safely stated therefore that any classification system is a reflection of the current state of knowledge of the universe under consideration and must be designed so as to permit the inclusion of new knowledge as it is discovered.

Smith (1963) stated that the system must be multi-categoric with a few taxa in the highest category and a large number in the lowest category. The reasons why this is so are: 1) the human mind can comprehend only a few things; and 2) the need to consider soils at different levels of generalization for different objectives.

Cline (1963) in logic of the new soil classification system, wrote that "the 'practical' role of the classes is to convey identity to otherwise unidentified real things in groups that can be interpreted. Interpretation of them requires at least one additional step of reasoning."

This is a very important concept and demands careful selection of criteria which are differentiating in the system. Cline further stated, "... the higher categories serve well only those whose interests are directly related to the specific purposes for which the criteria of the system have been selected. The classes of the lowest category can be used for a variety of objectives because they are most homogeneous in terms of entire sets of soil properties." In coining names for the system, five principles were followed; of this, (Smith1963) wrote: "1) The formative elements were to come from the classical languages insofar as possible; 2) The name should indicate the place of a taxon in the system. From the name one should be able to recognize both the category of the taxon and the taxa in any of the higher categories to which it belongs; 3) The names should be as short as possible. This is especially critical at the higher categories if the names of taxa in lower categories are to be manageable in speech; 4) The names should be as euphonic as possibl(e) 5) Existing terms were to be avoided." Sometimes these objectives conflicted and some of these problems are discussed by Heller (1963).

Tavernier (1963) said, "The classification scheme as it now stands, although incomplete and capable of improvement, is by far the most comprehensive, the most precise and the most nearly logical system that has been developed in any country."

## SOIL CLASSIFICATION

### General Statement

Any soil classification system which attempts to group members of a population into taxa which permit interpretations for man's use and management must provide means of evaluating by measurement or inference those soil properties important to the specified objective. Soil Taxonomy is such a system. It can provide the necessary quantitative information for most soil interpretations needed for management decisions.

The classification system chosen for the soil component is Soil Taxonomy, a basic system of soil classification for making and interpreting soil surveys. This system is in current use in the United States and many other countries.

The differentiating characteristics are soil properties that can either be measured or inferred and those differentiating characteristics with many accessory properties are preferred over those with few accessory properties.

The differentiating criteria are propoerties of the soils but the classes at the higher categories were predetermined by practical experience and genetic biases such as the decision to separate soils of arid regions from others which may have similar morphological features. The principles of naming were largely fulfilled.

The system is now in use in the United States and is the only official system in this country. In some European countries and in much of Central and South America the system is used to varying degrees as well as in some middle eastern countries.

Soil taxonomy is largely a quantitative system. The properties used to differentiate classes must be measured by prescribed methods. This is the main strength of the system but it also is one of the main weaknesses in that laboratory data are scarce and are difficult and expensive to obtain. Current costs of completing a soils inventory range from about 40 cents per acre for a low intensity inventory to about $1.00 per acre for a high intensity inventory.

The level of generalization required to answer specific questions determines the intensity of the inventory. The highest level of generalization, the highest categorical level, permits the least number of specific statements to be made about soils. The lowest categorical level soil series permits the largest number of specific statements; this is the level of the high intensity survey. For non-cultivated soils it is not always necessary to inventory at the lowest categorical level except in specific cases where information is required on small areas to solve special problems.

Soil Taxonomy is now sufficiently complete to enable all known soils in the United States to be classified at some level of generalization. Once the management questions have been asked the categorical level of soil taxonomy can be selected to accommodate the decision.

Orders

Soil Taxonomy has the following categories: Order, Suborder, Great Group, Subgroup, Family, and Series. The Order is the highest category, is the highest level of generalization, and contains the least specific information. The soil Series is the lowest level of generalization and contains the most specific information. In other words, we accrue information about our population as we go from higher to lower categories in the system.

The soil Order groups soils with similar kinds of major horizons. Kinds of surface soils and subsoils are definitive at the Order level. And it must be borne in mind that things which are separated by a differentiating property of generalization at high levels are also separated at low levels of generalization by the same property.

There are 10 Orders (Table 1 appendix). They are Alfisols, Ardisols, Entisols, Histosols, Inceptisols, Mollisols, Oxisols, Spodosols, Ultisols, and Vertisols.

Alfisols are soils with clay accumulations in the subsoil and have medium base saturation more than 35%. These are the soils in many of the forests in the western United States.

Ardisols are soils that are usually dry (more than 15 bar) in most years when not frozen or irrigated. These are the soils in many of the valleys in the western states.

Entisols are soils with little horizon differentiation. These are young soils; alluvial soils are examples of Entisols.

Histosols are organic soils. Peat and muck are examples.

Inceptisols are also young soils but show a higher degree of horizon differentiation than the Entisols. These are common on young landscapes, such as areas covered by late glaciation or volcanic ash, in the Uinta Mountains and on the Wasatch Plateau.

Mollisols are soils with dark-colored surface horizons and high base saturation (more than 50%). These soils are common in the mountains and high elevation valleys in Utah.

Oxisols are weathered soils of tropical areas. In general, these soils have low base status and low cation retention. Many have material which hardens on exposure to wetting and drying. This material which hardens is called plinthite which replaces the term laterite. After hardening the material is designated as iron-stone.

Spodosols are soils with accumulations of humus, aluminum and iron in the subsoils. They characteristically have low base saturation.

Ultisols are similar to Alfisols except they have lower base saturation (<35%) than Alfisols. They have clay accumulations in the subsoil. These soils are common in southeastern United States.

Vertisols contain clays which shrink and swell when dry and wet and cracks develop during dry periods. These have been called Grumosols and self-mulching soils. They are widely distributed throughout western U.S.

The orders which are most common in the Intermountain West are Alfisols, Ardisols, Entisols, Inceptisols and Mollisols (Table 2 Appendix).

Suborders. The Suborder category is the next lowest level of generalization. This level furnishes all the information available at the Order level plus the properties which are differentiating and accessory at the Suborder. Special kinds of horizons and moisture regimes of the soils are important criteria at the Suborder level. The Suborder name is formed by adding to the formative element of the Order, the root that connotes the differentiating property at Suborder (Table 2, Appendix). There are 47 Suborders.

The Great Groups. The Great Groups are formed by adding to the Suborder name prefixes which connote properties such as horizons of accumulation and the substance accumulated. In some Great Groups, climate is also used as a differentiating criterion. There are 185 Great Groups in the United States. For an abbreviated list, see Table 2, Appendix.

Subgroups are formed by adding (prefix) one or more adjectives in front of the Great Group name. These adjectives indicate the typical concepts or the transitions to other Great Group or Orders. An example is Duric Natrargid. This is the Subgroup designation and indicates the presence of a duripan and suggests the transition to a Nadurargid, another Subgroup of the Suborder Argids. The Subgroup is the lowest category to use elements derived from Latin and Greek.

Family. The Family level of generalization was the last category to be developed. It has proved to be a useful level of abstraction and as methods become available to quantify some of the parameters the category will be much more useful. The Family names are formed by adding to the Subgroup name the particle size, temperature and mineralogy names.

The particle sizes are silty, loam, sandy, clayey, with the words "fine" and "coarse" used to indicate subdivision within the loamy and sandy classes. "Skeletal" and "fragmental" are used to designate material larger than 2mm in diameter when it occupies more than 35% of the soil volume. Soil temperatures in soil families are measured at 50cm below the soil surface and the following classes are established. Mean annual soil temperatures where the difference between winter and summer temperatures is more than 5°C; less than 8°C, frigid; 8-15°C, mesic; 15-22°C, thermic; and more than 22°C, hyperthermic. Where the mean annual soil temperatures vary less than 5°C between winter and summer the prefix "iso" is added to each of the above classes and form isofrigid, isometric, isothermic, and isohyperthermic classes. In any management unit in the Intermountain area there will usually be not more than 3 temperature classes and often only 1 or 2.

Soil mineralogy at the family level is used to denote the kinds of minerals. This permits several interpretations about soil response to management. Examples of the names used in naming mineral types are Montmorillonitic, Kaolinitic and mixed. There are some other classes used at the family level but these are of minor extent when the whole universe of soil is considered. An example of a complete designation at the family level is loamy-skeletal mixed, mesic family of Typic Durargids.

Series. The lowest category in the system is the soil Series (Table 3 Appendix). This category contains the most information for classification and phases of the soil Series is the unit used in high intensity detailed mapping.

The soil Series is analagous to a polypedon (polypedon is a group of contiguous pedons). Pedon is the smallest 3-dimensional unit of soil which repeats itself in the landscape and is analogous to the unit cell of a crystal. In general the pedon is 1 meter on a side and 2 meters deep or deep enough to encompass soil horizon differentiation. The soil Series is characterized by a typifying pedon and a range of characteristics which other pedons may have and still belong to the same polypedon or soil Series. The soil Series to be recognized should be of sufficient size to permit delineation on maps of conventional scale usually 4" = 1 mile or 8" = 1 mile.

The soil phase is not a category of the classification system but is used at any categorical level to reflect properties which influence man's use and management. For example, stoniness is considered a phase criterion. Therefore, we may have stony soils, stony Xerolls at the Sub-order or stony Natrargids at the Great Group or of "X" stony loam at the series level.

A complete name at the Series level is the "X" Series is a member of a loamy-skeletal, mixed, mesic family of Lithic Natrargids. At this level we know from the name along with several properties of the soil without having seen the soil or without having data available. The information at each level of generalization is presented in the next section.

## IMPLEMENTATION PROCEDURES

The data recorded in the field for each horizon of each pedon described is thickness, color, texture, structure, consistence, root and pore distribution, and boundary conditions with the next lower contiguous horizon. Optional data are pH and degree of effervescence with HCl or other reagents to qualitatively detect the presence of various salt accumulations.

Data collected for each horizon of each pedon sampled for laboratory determinations are particle size distribution, including coarse fragments; pH, 1/3 and 15 bar moisture, electrical conductivity, calcium carbonate equivalent, cation exchange capacity and extractable cations, organic carbon and nitrogen. Other determinations may be added as needed locally. Collectively the laboratory and field data are referred to as "Characterization data" and both are needed to classify the soils in Soil Taxonomy. This does not mean that each time a pedon is described it is sampled for laboratory analysis but enough pedons should be described, sampled and analyzed to determine base data for extrapolation to other pedons. These characterization data establish the limits for the range in characteristics for each soil Series.

The most detailed information available for interpretations is at the Soil Series level. All the information about the soil is available at this level and interpretations can be made for areas such as portions of small watersheds. This level is used in differentiating between parts of landforms or different slope exposures (aspect).

The family level can be considered a grouping of series which have a similar particle size class, mineralogy and temperature regime. This is a useful level for interpreting soils on a small watershed. Differentiations within a single landform may be possible. This would be a useful level at the Ranger District level. Statements about slope stability, erosion and sedimentation are possible at this level.

The Great Group and the Subgroup do not differentiate among landforms but usually encompass more than one landform. The soil association map of Utah is at the Subgroup level (Wilson 1975). This level provides general information about the setting of the soils and general statements about the kinds of vegetation and climate. More specific statements about sedimentation and erosion potential or slope stability are not possible at this level. This category provides general information for management decisions at the National Forest level.

The Order and Suborder levels of generalization are used at the Regional and National levels.

The United States is mapped at the Suborder level. This provides general information about the zonal character - climate and vegetation - with some soil properties such as major kinds of soil horizons and a very general idea of base status or reaction.

Two levels of generalization appear to furnish information which permit interpretations likely needed for most management decisions. These are the Suborder for a general interpretation requiring few specific soil properties and the soil family where many specific soil properties are required. These levels are not site specific in the general sense but classification of a specific site can be made at the family level.

## MAPPING

The soils are classified and mapped according to standard procedures established by the Soil Survey Staff. A reconnaissance is conducted by stereoscopic study of the aerial contact prints accompanied by on-site observations. Geologic maps of the area were used to determine general relationships of parent materials to the kinds of soil. The vegetation and relief were studied to determine their relationship to the soils. Many holes were escavated to expose the sequences of natural layers or horizons in a soil which generally extend from the surface down into the parent material. Comparisons were made of these pedons and mapping units were established. Because of the complex physiography of much of the area, it was necessary to set up a number of mapping units called "soil associations." A soil association consists of areas where two or more soils occur side by side in the landscape and there is no real necessity to separate them for the stated objectives of the survey. Each delineation of a association contains two or more dominant soils, and the pattern and relative proportions are about the same in all delineations so named. The name of a soil association consists of the names of the dominant soils, joined by a hyphen.

While the survey was in progress soil samples were collected by horizons from selected locations. The analytical data provide the basis for classification and also the basis of interpretations for management decisions.

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# APPENDIX

Table 1. Soil orders in new system and approximate equivalent in Great Soil Groups of 1938 Yearbook of Agriculture as modified in 1949.*

| Present Order | Approximate equivalents |
|---|---|
| 1. Entisols | Azonal soils, and some Low Humic Gley soils |
| 2. Vertisols | Grumusols. |
| 3. Inceptisols | Ando, Sol Brun Acide,some Brown Forest, Low-Humic Gley, and Humic Gley soils |
| 4. Ardisols | Desert, Reddish Desert, Sierozem, Solonchak, some Brown and Reddish Brown soils, and associated Solonetz. |
| 5. Mollisols | Chestnut, Chernozem, Brunizem (Prairie), Rendzinas, some Brown, Brown Forest, and associated Solonetz and Humic Gley soils |
| 6. Spodosol | Podzols, Brown Podzolic soils, and Ground-Water Podzols. |
| 7. Alfisols | Gray-Brown Podzolic, Gray Wooded soils, noncalcic Brown soils, Degraded Chernozem, and associated Planosols and some Half-Bag soils. |
| 8. Ultisols | Red-Yellow Podzolic soils, Reddish-Brown Lateritic soils of the U.S., and associated Planosols and Half-Bog soils. |
| 9. Oxisols | Laterite soils, Latosols. |
| 10. Histosols | Bog soils. |

* Adapted from 7th Approximation USDA, Soil Conservation Service, 1960.

# APPENDIX

Table 2. Selected Orders, Suborders, and Great Groups with Formative Elements, Their Derivation and Meaning*.

| Orders | Suborders | Great Groups | Formative Element | Derivation of formative element | Connotation of formative element |
|---|---|---|---|---|---|
| Entisol | | | ent. | Nonsense syllable | Recent |
| | Aquent | | Aqu | L. Aqua, water | Char. assoc. with wetness |
| | | Cryaquent | cry | Gr. Kryos, coldness | Cold |
| Inceptisol | | | ept | L. inceptum beginning | Inception |
| | Ochrept | | ochr | Gr. ochros, pale | Presence of light colored surface, ochric epipedon |
| | | Xerochrept | xer | Gr. xeros, dry | Annual dry season |
| Aridisol | | | id | L. aridus, dry | Arid |
| | Argid | | arg | L. argillia, white clay | Presence of an argillic horizon (a clay accumulation) |
| | | Natrargid | natr | Modified from natrium sodium | Presence of a natric horizon |
| Mollisol | | | oll | L. mollis, soft | Mollify |
| | Ustoll | | ust | L. ustus, burnt | Of dry climate usually hot in summer |
| | | Calciustoll | calc | Modified from calcium | A calcic horizon (calcium accumulation) |
| Alfisol | | | alf | Nonsense | Pedalfer |
| | Xerolf | | xer | Gr. xeros, dry | Annual dry season |
| | | Haploxeralf | hapl | Gr. haplous, simp. | Minimum horizon development |

*Adopted from 7th Approximation USDA, Soil Conservation Service, 1960.

# APPENDIX

Table 3. Names of taxa in each category.

| Order | Suborder | Great Group | Subgroup | Family | Series |
|---|---|---|---|---|---|
| Mollisol | Boroll | Cryoboroll | Typic Cyroboroll | Fine, mixed* | X |
| Aridisol | Orthid | Calciorthid | Ustollic Calciorthid | Loamy-skeletal mixed frigid | Y |
| Entisol | Fluvent | Torrifluvent | Xeric torrifluvent | Clayey montmorill-onitic (calcareous) | Z |

* Frigid temperature is implicit in Boroll and Cyroboroll names.